Use of Ambient Sediment Data In Risk Assessments

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Abstract. All sediments contain ambient levels of chemical constituents associated with the geological matrix itself, plus anthropogenic contributions. Sources such as automobile emissions, roadway and parking lot runoff, and historic industrial and mining activities have resulted in "baseline" or "ambient" levels of many organic and inorganic constituents in sediments around the world. These ambient levels differ regionally and are impacted by population density and level of industrialization of a given area. Regulatory agencies are recommending that ambient conditions should be considered during the risk characterization step of the ecological risk assessment, and that ambient conditions should not be used as a tool for screening out constituents of potential ecological concern. For areas where little information is available about ambient conditions, or where sample collection to determine ambient conditions is included as part of the risk assessment work plan, the regulator's approach has merit. Consideration of ambient conditions is appropriate in the risk characterization where the "incremental risk" of the site above the risk posed by ambient conditions needs to be considered. However, in some areas (e.g. San Francisco Bay, Chesapeake Bay, Puget Sound), ambient conditions are well studied, and information about ambient levels of organic and inorganic constituents in sediment is widely available. In areas such as these ambient data can be an important tool to help focus risk assessments on those constituents with true potential to drive site risk. The U.S. Navy has developed Ecological Risk Assessment Policy recommending that ambient levels be considered in the early stages of an ecological risk assessment to help focus investigations and assessments on key risk drivers. Specific guidance for application of statistical distribution shift tests has been developed to assist in implementing this policy. A case-study is presented to demonstrate how use of ambient data as a screening tool can help focus baseline risk assessments on those constituents that truly have the potential to drive site risk, and avoid the expenditure of resources to evaluate chemicals that are not different than ambient levels.

Problem Statement

Regulatory agencies have traditionally advocated addressing ambient, or background, concentrations of chemical constituents during risk characterization (Step 7) or risk management (Step 8) of the ERA. This is an appropriate action for sites where ambient data are lacking, or are being collected as part of the site investigation. However, in some areas, much effort has already taken place to characterize ambient conditions, and in these areas it is logical to consider ambient issues earlier in the risk assessment process. Consideration of ambient during the ERA Problem Formulation (Step 3) can help focus the list of contaminants of concern. Waiting until risk characterization or risk management to consider ambient conditions can result in unnecessary resources being spent on baseline risk assessments to evaluate chemical concentrations that are not different from ambient.

Case Study

The data presented here are sediment data from a site on the eastern side of San Francisco Bay. The data were chosen to illustrate specific points for the purposes of this presentation. The site will be referred to as "SF Bay Site 1" in this presentation. The ambient data are actual San Francisco Bay ambient sediment data collected by the San Francisco Bay Regional Monitoring Program and the Bay Protection and Toxic Clean-up Program. The data comprising the ambient data set are from the sampling stations identified in RWQCB 1998 as being representative of ambient conditions in San Francisco Bay.

Table 1 presents the comparison of SF Bay Site 1 sediment data to sediment ecological screening thresholds. As the table indicates, no sediment screening thresholds are available for aluminum. Maximum concentrations of arsenic, nickel, zinc, 4-DDT, and benzo(a)pyrene were all greater than the risk-based sediment screening thresholds (ER-Ls from Long, et. al 1995). Step 2 of the Superfund ERA Guidance dictates that all of these constituents should be carried forward to a baseline ecological risk assessment because maximum concentrations exceed ecological screening thresholds, or because ecological screening thresholds are not available.

Table 1. Comparison of SF Bay Site 1 Sediment Concentrations to Sediment Ecological Screening Thresholds

Analyte	SF Bay Site 1 Maximum Concentration	Risk-based Sediment Screening Threshold (ER-L)*	Maximum > Screening Threshold?
Aluminum	39700 mg/kg	Not Available	No Threshold
Arsenic	11.9 mg/kg	8.2 mg/kg	Yes
Nickel	99 mg/kg	20.9 mg/kg	Yes
Zinc	210 mg/kg	150 mg/kg	Yes
4,4-DDT	12 ug/kg	1 ug/kg	Yes
Benzo(a)pyrene	660 ug/kg	430 ug/kg	Yes

*ER-L = Effects Range-Low from Long, et. al 1995.

Various regulatory agencies have suggested that comparisons to ambient conditions should take place during risk characterization or risk management. This approach is appropriately conservative for areas where ambient conditions represent an information gap that is being evaluated as part of the site investigation process. Using the regulator recommended approach, all of the chemicals in this example would be carried through a baseline ecological risk assessment. However, in areas where ambient conditions have already been well characterized, ambient data can be an important tool to help focus the ecological problem formulation. The U.S. Navy has published policy and guidance for evaluating ambient conditions in risk assessments. The "Navy Interim Final Policy on the Use of Background Chemical Levels" (Navy 2000) dictates that ambient conditions should be evaluated during Step 3A of the ERA, the COPC refinement step of the baseline ecological risk assessment. This example follows the Navy process for evaluating ambient conditions*. There are important caveats which must be considered prior to evaluation of ambient conditions. One of these is that site sediments and ambient sediments should be physically similar, particularly in regard to sediment grain size, as finer-grained sediments typically contain higher concentrations of chemical constituents. In the evaluation of San Francisco Bay ambient conditions, the San Francisco Regional Water Quality Control Board divided sediments into two categories; greater than 40% fines, and less than 40% fines. Ambient data for all sediment grain sizes were used in this example.

Comparisons to Ambient

Figure 1 shows SF Bay Site 1 data plotted next to San Francisco Bay ambient data in box and whisker plots. The box in each plot represents the middle half of the data, i.e the 25th percentile to the 75th percentile. The line across each box represents the median value. The box plots present an easy visual way to quickly evaluate data distributions relative to each other. The plots show that concentrations of aluminum, arsenic and nickel are actually skewed lower than San Francisco Bay ambient data. Site concentrations of 4,4-DDT and benzo(a) pyrene fell within the range of ambient data, while the maximum zinc concentration at Site 1 exceeded the maximum ambient zinc concentration. Summary statistics for each constituent are presented in Table 2. The Navy Handbook for Statistical Analysis of Environmental Background Data (Navy 1999) provides guidance for conducting statisitcal comparisons of site data to ambient data. Four distributional tests were used to compared SF Bay Site 1 data with San Francisco Bay ambient data. The quantile test and the slippage test both look for differences in the right (upper) tails of the distributions. The Gehan test tests for differences in the medians of the site and ambient data, while the t-test looks for differences in the means of the data. Results of the four distributional comparisons are presented in Table 3. No differences were found in any of the tests for any of the constituents. Because the maximum zinc concentration at Site 1 exceeded the maximum ambient concentration, site and ambient concentrations were plotted versus % fines to determine if zinc concentrations exceeded the 90% ambient prediction interval based upon % fines (Figure 2).

Table 2. Summary Statistics for Chemical Concentrations in SF Bay Site 1 Sediments and Ambient Station Sediments.

	SF Bay Site 1					Ambient Stations				
	Concentrations (ppm)					Concentrations (ppm)				
Analyte	N/D	Minimum	Median	Mean	Maximum	N/D	Minimum	Median	Mean	Maximum
Aluminum	33/33	13240	22700	25000	39700	173/173	8584	26950	28900	59250
Arsenic	33/28	<0.75	6.6	6.112	11.9	194/194	3.6	10	10.68	29.41
Nickel	33/33	15.5	46.2	50.76	99	193/193	47.5	82.9	85.4	141
Zinc	33/33	26.6	82.1	96.35	210	194/194	50	107.5	107.4	191
		Concentrations (ppb)					Concentrations (ppb)			
Analyte	N/D	Minimum	Median	Mean	Maximum	N/D	Minimum	Median	Mean	Maximum
4,4'-DDT	33/3	<0.45	0.65	1.323	12	85/82	<0.0114*	0.61	1.616	15
Benzo(a)pyrene	33/17	97	155	201.8	660	192/192	1	135.5	156.4	808.2

N/D=number of samples/number of detects
* Detection Limit not reported; substituted half the minimum detected concentration

Table 3. Results of Distributional Comparisons of SF Bay Site 1 Data to SF Bay Ambient Data

	SF Bay Site 1		Ambient Stations		Test p-values				
Analyte	No. of samples	No. of Detects	No. of samples	No. of Detects	Gehan	Quantile	Slippage	t-test	Result
Aluminum	33	33	173	173	0.9731	0.8373	1	0.9863	Pass
Arsenic	33	28	193	193	>0.9999	>0.9999	1	>0.9999	Pass
Nickel	33	33	193	193	>0.9999	0.9997	1	>0.9999	Pass
Zinc	33	33	194	194	0.9447	0.08486	0.1454	0.8809	Pass
4,4'-DDT*	33	3*(33)	87	84	0.1228	0.9869	1	0.9261	Pass*
Benzo(a)pyrene	33	17	192	192	0.578	0.6885	1	0.3472	Pass

* Site detection rate too low to run standard tests. Modified tests were run by assuming that all the non-detects were detected at the reported detection limits.
Pass*: test result based on modified tests.

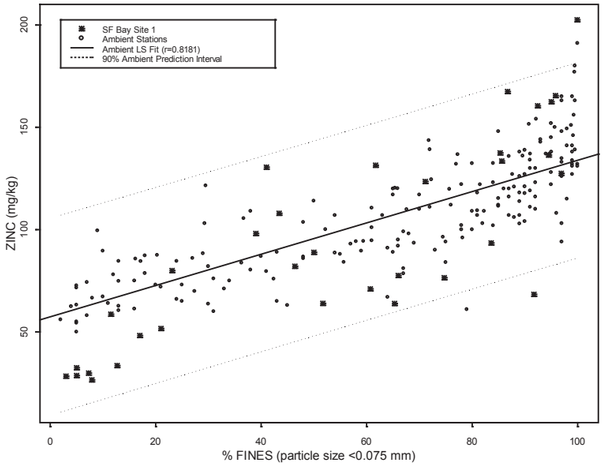

Figure 2. Ambient and SF Bay Site 1 Zinc Concentrations As a Function of % Fines

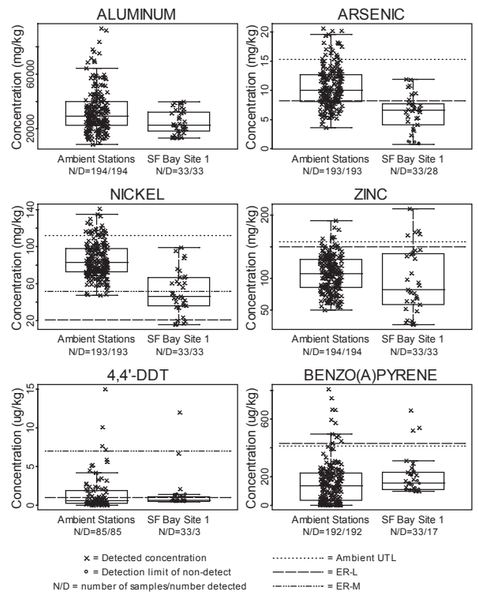

Figure 1. Boxplots Comparing Concentrations of "SF Bay Site 1" Sediment and San Francisco Bay Ambient Sediment.

Conclusions

Comparisons of concentrations of aluminum, arsenic, nickel, 4,4-DDT, and benzo(a)pyrene in SF Bay Site 1 sediments, with concentrations of the same constituents in San Francisco Bay ambient sediments, indicates that there is no difference between site and ambient conditions. As such, little information could be gained from further evaluation of these constituents in a baseline ERA, even though maximum concentrations exceed traditional sediment screening benchmarks. Although statistically not different from ambient, the box plots and mixing curve for zinc suggest that further evaluation of zinc is necessary to determine if the maximum observed concentration is the result of a localized release of zinc at SF Bay Site 1.

Literature Cited

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*The data presented in this presentation were chosen to illustrate specific principles, and the findings associated with this presentation are not intended to represent the Department of Navy.